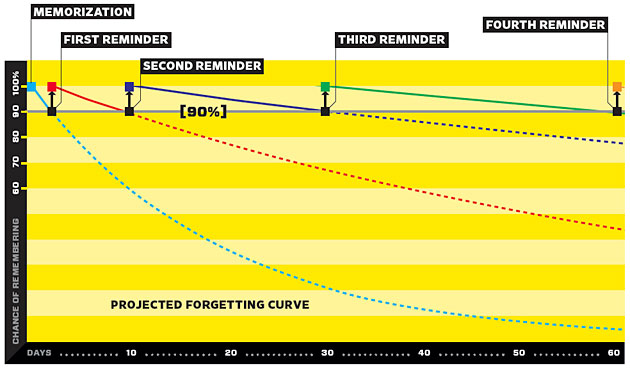
**Want to Remember Everything You'll Ever Learn? Surrender to This Algorithm**

**In the late 1800s,** a German scientist named Hermann Ebbinghaus made up lists of nonsense syllables and measured how long it took to forget and then relearn them. (Here is an example of the type of list he used: bes dek fel gup huf jeik mek meun pon daus dor gim ke4k be4p bCn hes.) In experiments of breathtaking rigor and tedium, Ebbinghaus practiced and recited from memory 2.5 nonsense syllables a second, then rested for a bit and started again. Maintaining a pace of rote mental athleticism that all students of foreign verb conjugation will regard with awe, Ebbinghaus trained this way for more than a year. Then, to show that the results he was getting weren't an accident, he repeated the entire set of experiments three years later. Finally, in 1885, he published a monograph called *Memory: A Contribution to Experimental Psychology*. The book became the founding classic of a new discipline.

Ebbinghaus discovered many lawlike regularities of mental life. He was the first to draw a learning curve. Among his original observations was an account of a strange phenomenon that would drive his successors half batty for the next century: the spacing effect.

Ebbinghaus showed that it's possible to dramatically improve learning by correctly spacing practice sessions. On one level, this finding is trivial; all students have been warned not to cram. But the efficiencies created by precise spacing are so large, and the improvement in performance so predictable, that from nearly the moment Ebbinghaus described the spacing effect, psychologists have been urging educators to use it to accelerate human progress. After all, there is a tremendous amount of material we might want to know. Time is short.

**How Supermemo Works**  
SuperMemo is a program that keeps track of discrete bits of information you've learned and want to retain. For example, say you're studying Spanish. Your chance of recalling a given word when you need it declines over time according to a predictable pattern. SuperMemo tracks this so-called forgetting curve and reminds you to rehearse your knowledge when your chance of recalling it has dropped to, say, 90 percent. When you first learn a new vocabulary word, your chance of recalling it will drop quickly. But after SuperMemo reminds you of the word, the rate of forgetting levels out. The [program](http://www.supermemo.com/articles/soft/smnet.htm) tracks this new decline and waits longer to quiz you the next time.



However, this technique never caught on. The spacing effect is "one of the most remarkable phenomena to emerge from laboratory research on learning," the psychologist Frank Dempster wrote in 1988, at the beginning of a typically sad encomium published in *American Psychologist* under the title "The Spacing Effect: A Case Study in the Failure to Apply the Results of Psychological Research." The sorrrowful tone is not hard to understand. How would computer scientists feel if people continued to use slide rules for engineering calculations? What if, centuries after the invention of spectacles, people still dealt with nearsightedness by holding things closer to their eyes? Psychologists who studied the spacing effect thought they possessed a solution to a problem that had frustrated humankind since before written language: how to remember what's been learned. But instead, the spacing effect became a reminder of the impotence of laboratory psychology.

As a student at the Poznan University of Technology in western Poland in the 1980s, Wozniak was overwhelmed by the sheer number of things he was expected to learn. But that wasn't his most troubling problem. He wasn't just trying to pass his exams; he was trying to learn. He couldn't help noticing that within a few months of completing a class, only a fraction of the knowledge he had so painfully acquired remained in his mind. Wozniak knew nothing of the spacing effect, but he knew that the methods at hand didn't work.

The most important challenge was English. Wozniak refused to be satisfied with the broken, half-learned English that so many otherwise smart students were stuck with. So he created an analog database, with each entry consisting of a question and answer on a piece of paper. Every time he reviewed a word, phrase, or fact, he meticulously noted the date and marked whether he had forgotten it. At the end of the session, he tallied the number of remembered and forgotten items. By 1984, a century after Ebbinghaus finished his second series of experiments on nonsense syllables, Wozniak's database contained 3,000 English words and phrases and 1,400 facts culled from biology, each with a complete repetition history. He was now prepared to ask himself an important question: How long would it take him to master the things he wanted to know?

The answer: too long. In fact, the answer was worse than too long. According to Wozniak's first calculations, success was impossible. The problem wasn't learning the material; it was retaining it. He found that 40 percent of his English vocabulary vanished over time. Sixty percent of his biology answers evaporated. Using some simple calculations, he figured out that with his normal method of study, it would require two hours of practice every day to learn and retain a modest English vocabulary of 15,000 words. For 30,000 words, Wozniak would need twice that time. This was impractical.

Wozniak's discouraging numbers were roughly consistent with the results that Ebbinghaus had recorded in his own experiments and that have been confirmed by other psychologists in the decades since. If students nonetheless manage to become expert in a few of the things they study, it's not because they retain the material from their lessons but because they specialize in a relatively narrow subfield where intense practice keeps their memory fresh. When it comes to language, the received wisdom is that immersion — usually amounting to actual immigration — is necessary to achieve fluency. On one hand, this is helpful advice. On the other hand, it's an awful commentary on the value of countless classroom hours. Learning things is easy. But remembering them — this is where a certain hopelessness sets in.

As Wozniak later wrote in describing the failure of his early learning system: "The process of increasing the size of my databases gradually progressed at the cost of knowledge retention." In other words, as his list grew, so did his forgetting. He was climbing a mountain of loose gravel and making less and less progress at each step.